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During the past year we have conducted several experiments designed to study those stimulus characteristics which contribute to the ability of the auditory system to separate simultaneous signals. We have studied the effects of sychroous amplitude modulation, specifically the influence of changes in relative level of two stimuli, and have found that by changing relative levels of the two stimuli involved, the ear can detect temporal synchrony over a range of at least four octaves. We have also studied the effects of simultaneous gating, synchronous FM, and harmonicity on the ability of the auditory system to detect a signal in the presence of other stimuli. We have found that each of these characteristics contribute to signal separation.

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Annual Technical Report for Grant No. AFOSR-89-0008

AUDITORY PERCEPTION

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30 NOV 1989

ABSTRACT

During the past year we have conducted several experiments designed to study those stimulus characteristics which contribute to the ability of the auditory system to separate simultaneous signals. We have studied the effects of synchronous amplitude modulation, specifically the influence of changes in relative level of two stimuli, and have found that by changing relative levels of the two stimuli involved, the ear can detect temporal synchrony over a range of at least four octaves. We have also studied the effects of simultaneous gating, synchronous FM, and harmonicity on the ability of the auditory system to detect a signal in the presence of other stimuli. We have found that each of these characteristics contribute to signal separation.

During the first year of this grant period, we have performed several experiments concerned with separation of simultaneous signals. They are described below.

Virtually all reports on comodulation masking released (CMR) show it to be a phenomenon whereby the cue and masker bands must be fairly close in frequency, say within one octave of each other, and that the improved signal detectability diminishes as the frequency separation of these two correlated noise bands increases. However, we now have data demonstrating a CMR when the cue and masker bands are separated by four octaves. Previously, we have shown that the detectability of a noise band diminishes when a temporally synchronous noise band is present at a distant frequency (Cohen & Schubert, 1987). We refer to this as cross-spectrum fusion and suggested that this may be mediated by the same mechanism as CMR, that CMR and cross-spectrum fusion were possibly different measurements of the same phenomenon. However, we could not reconcile the fact that for CMR, the largest effect occurred when the cue and masker bands were close in frequency, and the effect nearly disappeared when they were an octave apart, whereas for fusion, the greatest effect occurred when the two noise bands were separated by 2 octaves. The two noise bands were acoustically identical for the two paradigms, except for level. In the fusion paradigm, the level of the signal band was, of course, at detection threshold, and for the CMR experiments, the levels of the two noise bands were equal. With that in mind, we performed an experiment to determine if that level difference could in fact account for the differences in the results of the two experimental paradigms.

The experiment was performed to measure the effect on CMR of lowering the level of the masker band, while keeping the cue band at 78 dB SPL. The stimulus was composed of a signal to be detected and two 100-Hz-wide noise bands, one, the cue band, was centered at 1000 Hz, and the other, the masker band, varying in center frequency from 500 Hz to 8000 Hz in octave steps, not including 1000 Hz. The signal to be detected was a 50 ms tone-burst having the same frequency as the masker band. The temporal envelopes of the two noise bands were either correlated or independent. The overall level of the 1000 Hz cue band was always 78 dB SPL. The overall level of the masker band varied from 18 dB SPL to 78 dB SPL in 20 dB steps. The stimulus was presented to the right ear.

In general, results show very little CMR when the masker and cue bands are at equal levels, and the cue band is more than an octave removed from the signal and masker band. This may be considered the classic CMR paradigm. However, as the level of the masker band is decreased, a CMR of around 12 dB exists for a two octave separation, and of as much as 7 dB for a <u>three</u> octave separation. When the signal was closer in frequency to the cue

band, we recorded CMRs averaging as much as 16 dB. We repeated the experiment dichotically, with the cue band introduced only to the opposite ear, and noted similar results. The CMR was generally smaller, but still in the 5 dB range with a two octave separation. These data, Figure 1, show that the ear is able to recognize synchrony in temporal envelope across at least three octaves. Further, the dichotic data, Figure 2, demonstrate that this recognition does not necessarily result from peripheral interactions between the two noise bands. It should also be noted, that the CMR does not occur when the signal is lower in frequency (500 Hz) than the cue band.

This experiment was repeated with a 500 Hz cue band. Everything else was the same as described above. The results are shown in Figures 3 and 4. These data are similar to those described above, showing a CMR existing over a range of 4 octaves, and CMR decreasing when the masker and cue bands are equal in level.

Our second project involves simultaneous gating of signal and masker. One possible cue used by the auditory system to group information across frequency is signal onset and offset. If the auditory system uses this cue to determine which of several acoustic inputs belong together, then we might expect the same effect on detection when the signal and masker are gated together as we observed when both the signal and masker are temporally correlated. This experiment was done in an attempt to measure the effect of simultaneous gating on signal separation, as measured by the detectability of a noise-band signal in the presence of a simultaneously gated noise-band masker.

The stimulus was composed of two 100-Hz-wide noise bands, each one created by modulating a sinusoid by a 50-Hz low-pass noise. One of these bands, the signal band, varied in center frequency from 400 Hz to 6000 Hz. The second band, which we refer to as the masking band, was always centered at 500 Hz, had an overall level of 75 dB SPL, and was presented either continuously, or was gated simultaneously with the signal. Also, the 500 Hz noise band was either temporally correlated with the signal, or temporally independent, depending on whether the modulating noise came from the same or independent noise generator. The stimulus was presented diotically through TDH-49 headphones.

The results indicate that, in general, simultaneous gating results in poorer detection. When the signal was close in frequency to the masker, there was very little effect of gating the masker with the signal. However, as the signal frequency becomes farther removed from the masker frequency, the shift upward in detection threshold of the signal due to simultaneous gating of the masker increases to 9-11 dB. This pattern is similar for both the

correlated and independent conditions. These data indicate that simultaneous gating of two noise bands results in poorer detection of one of them, an effect similar to that observed when the two noise bands are temporally synchronous.

The third project in progress is preparation of a Letter to the Editor of JASA based on an ASA paper presented several years ago with Earl Schubert. This paper has been widely referenced, several times inaccurately, and so we think it should be submitted for the record. It involves data suggesting that the MLD and CMR are not totally independent.

Currently, we are performing experiments to determine how the ear uses frequency modulation and harmonicity to separate simultaneous signals. These experimental paradigms are similar to previous experiments we have done on cross-spectrum fusion, except that the amplitude modulation of the cue and masker bands is replaced with frequency modulation or the signal and masker are or are not harmonically related. Our data so far show that there is a very large effect, as much as 20 dB, on detection threshold of an FM signal when the frequency change is going in the same direction as that of the masker. This occurs when the signal and masker are several octaves apart.

With regard to the effects of harmonicity on signal separation. Our results to date indicate that a signal is more difficult to detect in the presence of a second stimulus at another frequency when the two are harmonically related. For example, in the presence of a 220 Hz and 440 Hz stimulus, a signal of 1100 Hz will be less detectable than one of 1087 Hz. We are still collecting data for these two experiments.

During this first year of the grant, we have established a new laboratory setup. We are now able to have greater flexibility in producing and presenting stimuli. Our new equipment provides us with four channels so that we can now perform some of the dichotic experiments that we could not do previously. Also, we are creating our FM stimuli digitally, thereby gaining the much needed control of these stimuli. And, as noted above, our results to this time seem promising.

Meeting Papers:

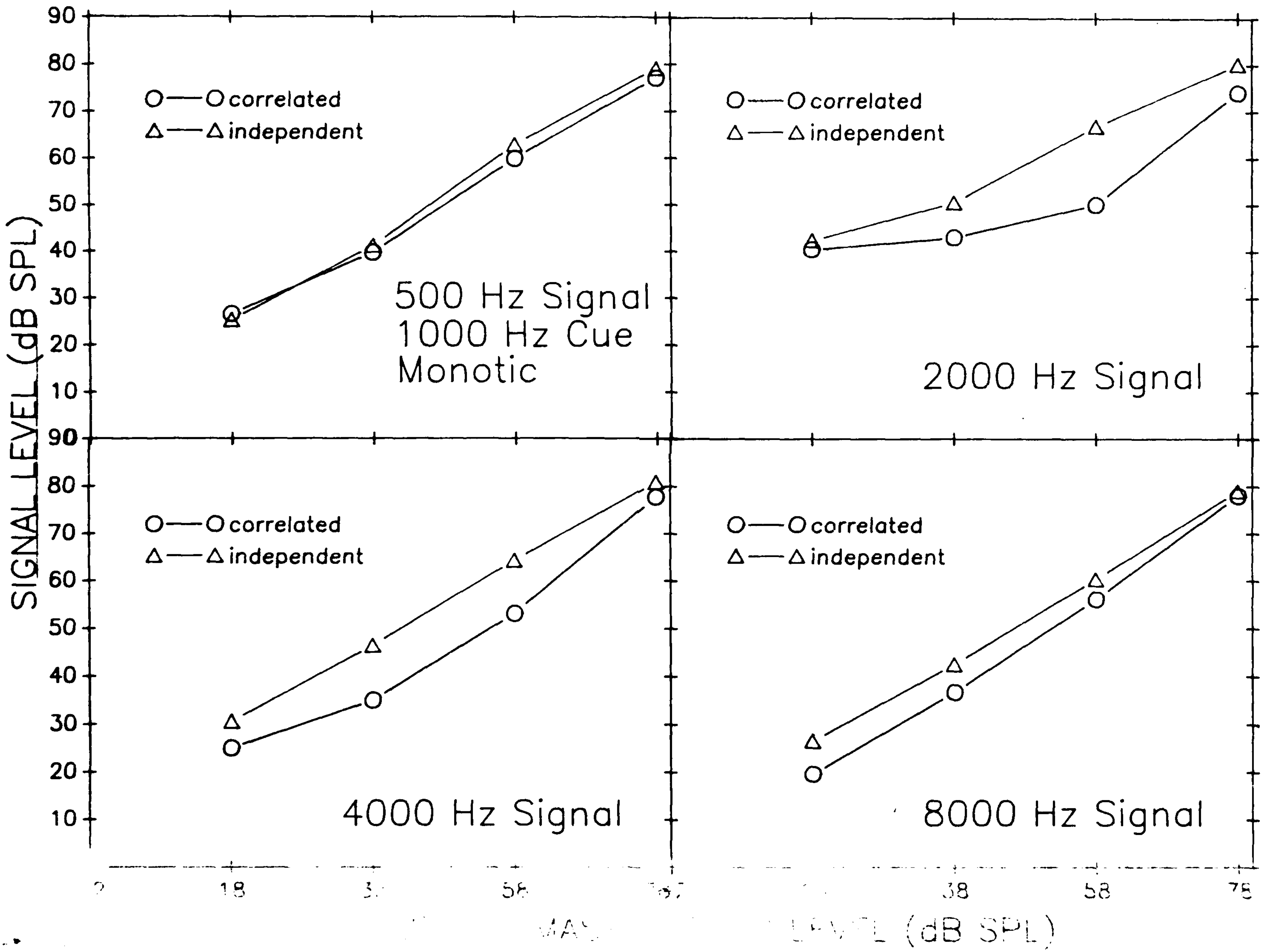
Cohen, Marion F. (1989). "Increased CMR resulting from lowered levels of masker band," To be presented at the Fall, 1989 meeting of The Acoustical Society of America.

Manuscripts in Progress:

Cohen, M.F. and Schubert, E.D. "Comodulation masking release and the masking-level difference," to be submitted as a Letter to the Editor, J. Acoust. Soc. Am.

Cohen, Marion F. "Increased CMR resulting from lowered levels of masker band," to be submitted to J. Acoust. Soc. Am.

Cohen, Marion F. "The effect of simultaneous gating on signal separation," to be submitted to J. Acoust. Soc. Am.



SIGNAL LEVEL (dB SPL)
O—O correlated
Δ—Δ independent
500 Hz Signal
1000 Hz Cue
Monotic
2000 Hz Signal
4000 Hz Signal
8000 Hz Signal
18
58
38
75
(dB SPL)

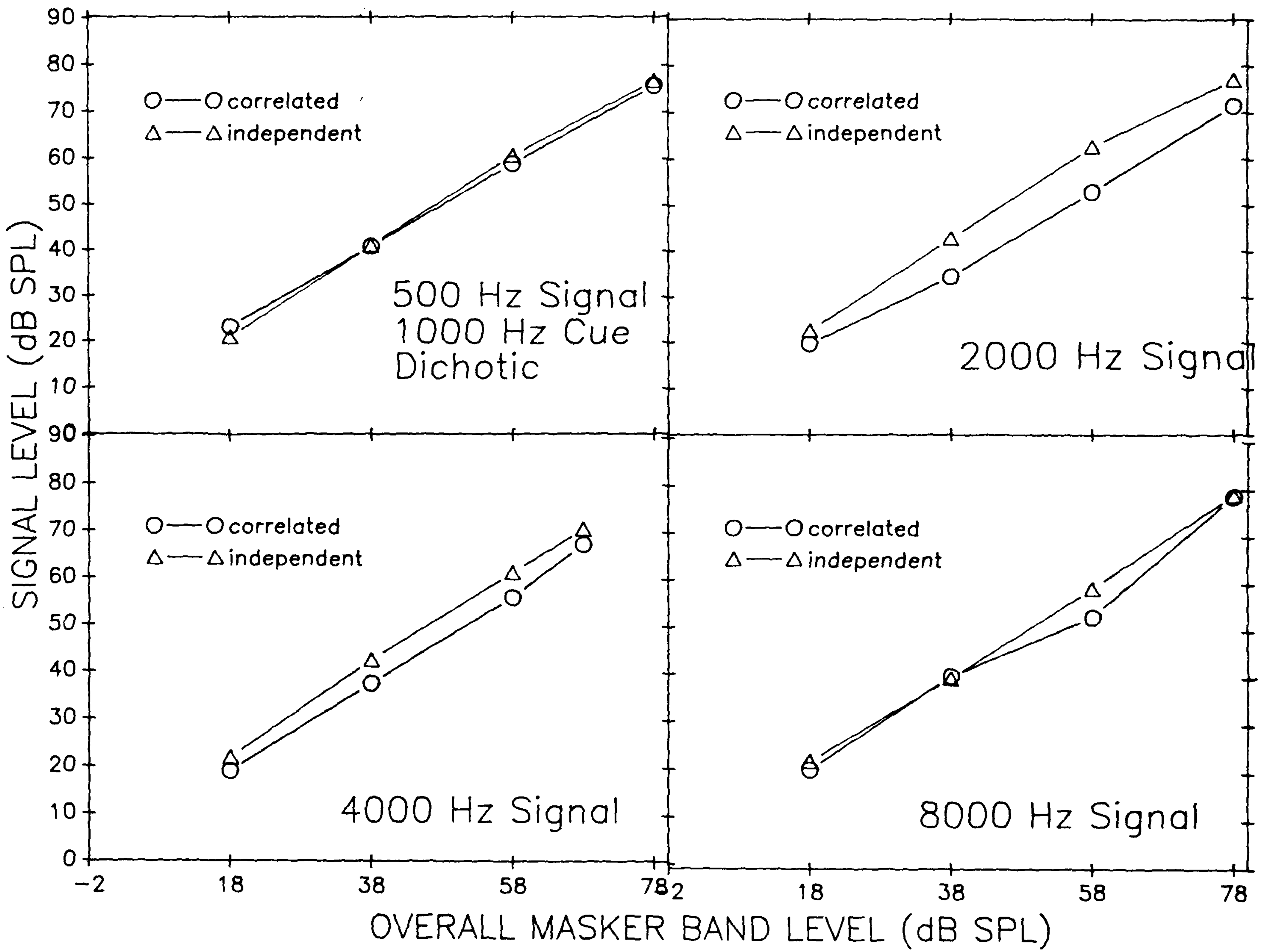
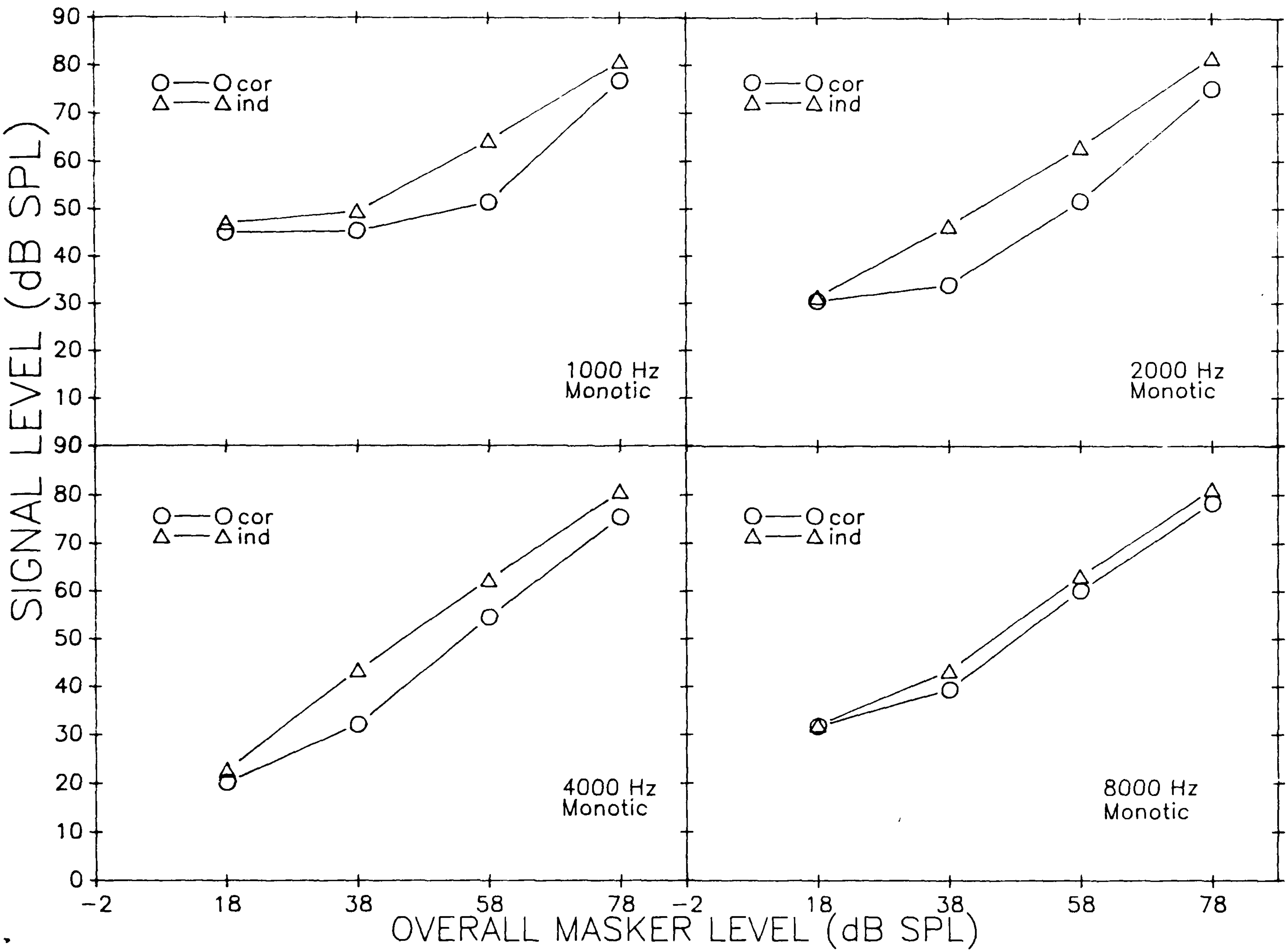
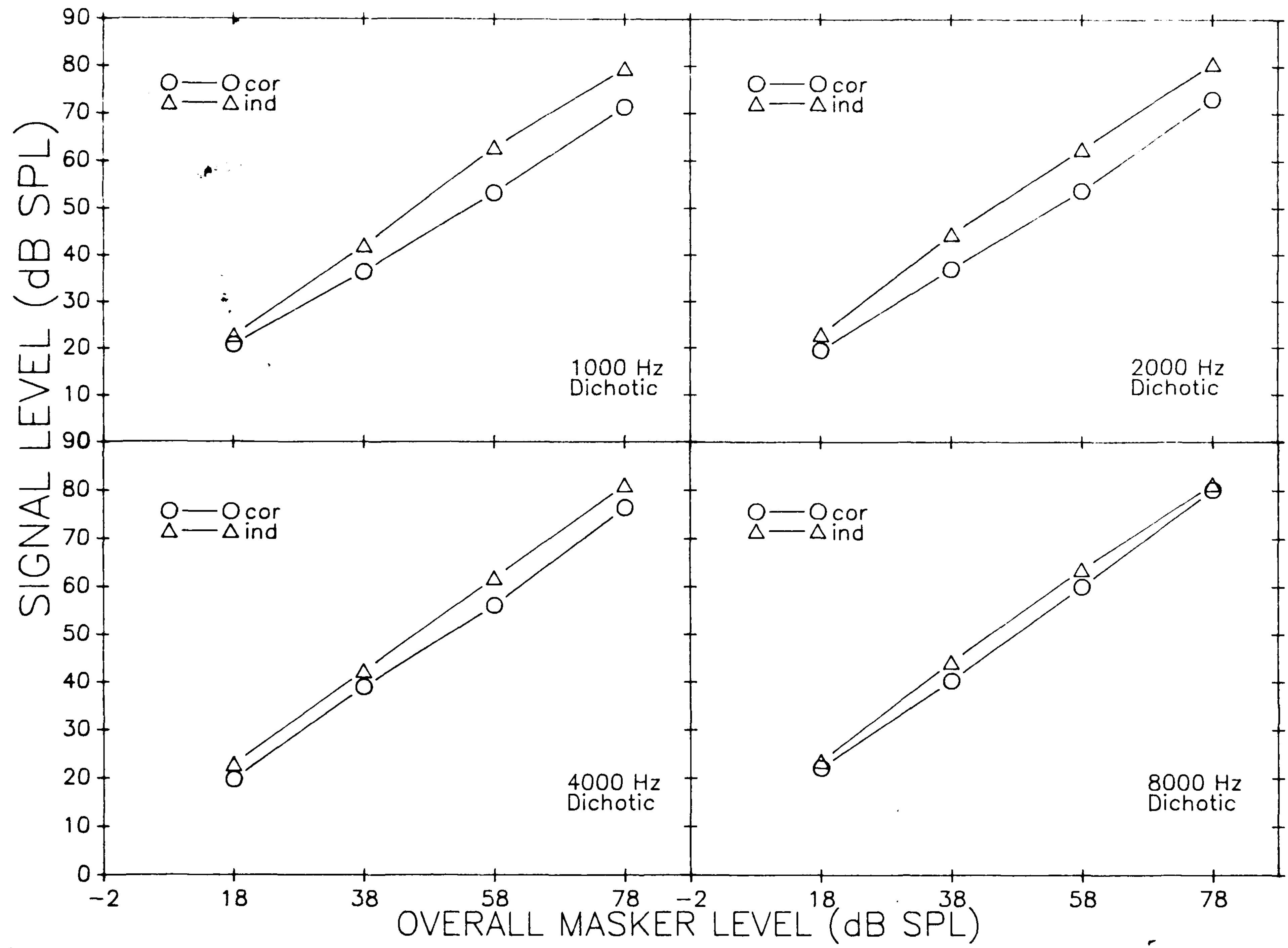

SIGNAL LEVEL (dB SPL)
OVERALL MASKER BAND LEVEL (dB SPL)
O—O correlated
Δ—Δ independent
500 Hz Signal
1000 Hz Cue
Dichotic
2000 Hz Signal
4000 Hz Signal
8000 Hz Signal
0
10
20
30
40
50
60
70
80
90
−2
18
38
58
78

Fig 2


SIGNAL LEVEL (dB SPL)
OVERALL MASKER LEVEL (dB SPL)
○—○ cor
△—△ ind
1000 Hz
Monotic
2000 Hz
Monotic
4000 Hz
Monotic
8000 Hz
Monotic
0
10
20
30
40
50
60
70
80
90
−2
18
38
58
78



SIGNAL LEVEL (dB SPL)
OVERALL MASKER LEVEL (dB SPL)
O—O cor
Δ—Δ ind
1000 Hz
Dichotic
2000 Hz
Dichotic
4000 Hz
Dichotic
8000 Hz
Dichotic